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ANCIENT PANAMA CANALS*

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The faunal relations of the Atlantic and Pacific have at various times received the attention of many eminent zoologists and paleontologists. Recent discoveries and investigations in the Miocene, Oligocene and Eocene of the Pacific Coast and Caribbean have caused the writer to review this subject again. One of the principal results of this work is definite proof of connections across Panama and Tehuantepec portals during the Bowden stage. The Bowden stage in Florida, the Alum Bluff formation, *Orthaulax pugnax* zone and associated zones are not upper Oligocene but middle or lower Miocene. The Oligocene of the Pacific Coast contains no species in common with the Bowden stage and the stage of evolution of the Bowden fauna is far more advanced than that of the enormously thick strata (10,000 to 15,000 feet) of the west coast Oligocene. A brief review of the geology of the Caribbean and Central American areas is given below.

A basement complex of granites and schists of unknown age occurs in Mexico and Central America. In this portion of the Antillean Province both upper and lower Cretaceous rocks are found and there are a few scattering locations of Carboniferous and other Paleozoic rocks. Upper Cretaceous rocks are

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found in all of the larger islands of the Caribbean. These rocks consist of shales, limestones, sandstones and igneous rocks of various types. In certain places throughout the entire region, rocks of Eocene age have been identified. For example, along the Mexican Gulf border, and in Jamaica, Cuba, Santa Domingo, and possibly, in the Tehuantepec Isthmus, rocks of this age occur.

The Oligocene, Vicksburg stage, occurs sparingly along the Mexican Gulf border, and its southernmost appearance is, according to Dall¹ in Costa Rica. Beds of this same age are also reported by Hill in Cuba. According to Hill² the Barbadoes pteropod chert, chalks and red clay occur in Cuba unconformably below the Bowden and he suggests that they are equivalent in age to the Vicksburg.

Resting unconformably upon all of the older formations is a series of beds bearing the Bowden fauna. The unconformity between the Bowden and the above described beds is a very great one and the erosion interval probably represents a great portion of Oligocene time, at least. Beds bearing the Bowden fauna are known from the Isthmus of Tehuantepec, Isthmus of Panama, Zuluzum (Mexico), Cuba, Jamaica, Porto Rico, Trinidad, Windward and Leeward islands, and, according to the collection of Anderson and Martin, in the vicinity of Cartagena, United States of Colombia. Upon a diastrophic basis the age of the beds containing this fauna appears to be Miocene.

Minor occurrences of Pliocene occur in the Mexican Gulf border, Colombia and Yucatan, where it merges imperceptibly with the Pleistocene according to Heilprin³ and others.

Pleistocene beds are reported at several different elevations on all of the islands of the Greater Antilles as well as the small islands of Barbadoes, where terraces are found at an elevation of 1000 feet. Pleistocene terraces occur upon both sides of the Isthmus of Panama, and upon both sides of the Isthmus of Tehuantepec, but no evidence indicates a Pleistocene canal in either one of these portals. (See below.) Jordan⁴ states that the fish faunas of the Panamian and Caribbean are substan-

¹ Dall, W. H., in Hill's *Geology of the Isthmus of Panama*, Bull. Mus. Comp. Zool., vol. 28, 275, 1898.

² Hill, R. T., *Notes on the Geology of the Island of Cuba*, Bull. Mus. Comp. Zool., vol. 16, 253, 1895.

³ Heilprin, A., *Geological Researches in Yucatan*, Proc. Acad. Sci., Phila., 136, 1891.

⁴ Jordan, D. S., Proc. U. S. Nat. Mus., vol. 8, 361, 1895.

tially distinct, but six per cent of species being common. Evermann and Jenkins⁵ who studied the problem more in detail recognized 1307 species on the Panama side. Ruling out 16 of these owing to their very wide distribution, they determined that approximately 4.3 per cent were common to the two shores.

Belt,⁶ a naturalist in Nicaragua, estimates the Caribbean marine molluscan fauna at 1500 species and the Panamic fauna at 1341. Of these, but 50 are common to the two shores.

A. Agassiz⁷ states that all but three of the Pacific echinoid genera are represented in the Caribbean, but he recognized no common species. Ortmann, who later studied the echinoderms from these two regions, states that even genera and families show a remarkable contrast and that there are no species in common. Verrill⁸ states that no species of corals in these two provinces are identical. Genera and families of reef building corals of the Caribbean Province are, except *Porites*, absent from the Panamic region whereas *Meandrina*, *Diploria*, *Manicina*, *Colpophyllia*, *Agaricia*, *Siderastræa* (*Astrea*), *Oculina*, *Madrepora* and *Millepora* are abundant in the Caribbean. *Pocillopora*, *Montipora*, *Pavonia*, are characteristic Pacific genera and do not occur in the Caribbean. From this evidence he concludes that there has been no connection between the Atlantic and Pacific oceans since early Tertiary.

Brown and Pilsbry⁹ state that the genera *Cymia*, *Solenosteira*, *Strombina*, *Malca*, *Trachycardium*, of *belcheri* group, *Clementia*, *Acila*, *Tesseracme*, *Cadulus*, characteristic Bowden genera—none of which is a deep water form—occur in the recent fauna of the Panamic province. None of these genera occurs in the recent Antillean fauna, hence one concludes that the Panamic fauna developed from a Bowden stock of probably early Miocene age.

Spencer¹⁰ postulates Pliocene canals through the Isthmus of Tehuantepec. Bose and Toula¹¹ who have studied the Isthmus of Tehuantepec, disagree entirely with Spencer's geologic data and state that it is impossible to trace marine terraces across

⁵ Evermann, Barton W., and Jenkins, Oliver P., Proc. U. S. Nat. Mus., vol. 14, 126, 1891.

⁶ Belt, Thomas, The Naturalist in Nicaragua, London, 247, 1888.

⁷ Agassiz, A., Bull. Mus. Comp. Zool., vol. 1, p. 301, 1869.

⁸ Verrill, A. E., Proc. Essex Institute, 323, 1866.

⁹ Pilsbry, H. A., and Brown, A. P., Proc. Acad. Sci. Phila., 1911, 336.

¹⁰ Spencer, J. W., Bull. Geol. Soc. Amer. vol. 8, 13-34, 1897.

¹¹ Bose, E., and Toula, F., Zur Jungtertiären Fauna von Tehuantepec, Jahrbuch der kaiserlich-königlichen Geologischen Reichsanstalt, 215, 1910.

the Isthmus although they recognize the presence of stream-laid deposits resting upon rocks bearing a Bowden fauna. The faunal evidence along the various lines discussed above in no manner indicates any recent connections.

Dr. T. W. Vaughan recently published a professional paper, *The Reef-Coral Fauna of Carrizo Creek, Imperial County, California, and Its Significance*, which gives decided support to Spencer's views. Vaughan's conclusions concerning the interesting coral fauna obtained from the head of the Gulf of California are:

“1. The Carrizo Creek reef-coral fauna is Atlantic, not Pacific, in its affinities.

2. During Eocene and Oligocene time there was connection between the Atlantic and Pacific oceans across Central America, and there was no sharp differentiation between the Atlantic and Pacific faunas.

3. Upper Oligocene (Apalachicolan) time was closed by diastrophic and other geologic events of profound importance, which separated the Atlantic from the Pacific Ocean by forming a land area extending from North to South America. During Miocene time sharp differentiation between the Atlantic and Pacific faunas took place, largely by the extinction of the Pacific elements in the Atlantic area.

4. The Pliocene coral fauna of Florida is purely Atlantic in its affinities, and since Pliocene time there has been only minor modification of the coral fauna in the western Atlantic, the Gulf of Mexico, and the Carribbean Sea.

5. The fauna of Carrizo Creek is related to Pliocene and post-Pliocene faunas of Florida and the West Indies and can scarcely be older than lower Pliocene.

6. Subsequent to the differentiation between the Atlantic and Pacific faunas there was in upper Miocene or Pliocene time inter-oceanic connection, which permitted the Atlantic fauna to extend into the Gulf of California and up to its head, and conditions not yet understood excluded the Pacific fauna from the area.

7. The locus of the inferred interoceanic connection is not known. It was probably in the region of the Isthmus of Tehauntepec, or farther southeast.”

His statement concerning the Atlantic affinities of this fauna receives strong support when the gastropods and pelecypods are studied as well. All the coral genera recognized in this assemblage except one occur in the Bowden or associated horizons. His conclusions concerning the Pliocene age of these beds rests upon the infirm basis of comparison with a Pliocene coral fauna from Florida. Conrad in Volume 5 of the Pacific Railroad Reports, says that "the *Ostrea vespertina*, *Anomia subcostata*, and *Pecten deserti* occurring in the banks of Carrizo Creek are unlike any recent forms that I am acquainted with from the Pacific Coast, but analogous to Miocene species of Virginia. This formation may therefore be regarded as of Miocene origin." Conrad's early recognition of the Atlantic facies in this fauna and his conclusions concerning its age appear to the writer to be essentially correct. Spencer and Vaughan's conclusions concerning Pliocene connections between the Atlantic and Pacific appear very doubtful. This problem will be discussed at length in another paper.

The Bowden fauna which typically occurs in Jamaica is very widespread and the relationship between the recent Panamic fauna and the Bowden fauna is an intimate one. The wide spread submergence of the Antillean lands is also evidence which points to the occurrence of shallow connections at least through the two isthmuses during the Miocene. This submergence was so great at this stage that most of the Antillean islands were vastly decreased in area.

The recent discovery of *Merychippus*,¹² a horse characteristic of the Miocene, associated with other Miocene vertebrates, in the Alum Bluff formation of Florida, a Bowden equivalent or associated horizon, gives us conclusive proof of the Miocene age of these beds.

According to Professor J. C. Merriam,¹³ this species of *Merychippus* represents essentially the same stage in evolution as one of the recently discovered horses of the Tehachapi Mountains region of California. These continental deposits of the Tehachapi Mountains according to Merriam and Buwalda, represent middle Miocene or the upper portion of the lower Miocene. Evidently these two faunas will prove of

¹² Sellards, E. H., Eighth Annual Report, Florida Geological Survey, 87-88, 1916.

¹³ Merriam, J. C., in Eighth Annual Report, Florida Geological Survey, 88, 1916.

great value in giving paleontologists an excellent connection with the Miocene of America, since of all forms in the Tertiary the stages of the horse are best known.

Finally, a Tertiary fauna from Magdalena Bay, Lower California, was recently discovered and submitted to Dr. B. L. Clark of the University of California for identification. This fauna as determined by Dr. Clark and the writer contains the following species: *Ræta gibbosa* Gabb, *Pecten oxygonum optimum* Brown & Pilsbry, *Pecten condylomatus* Dall, *Pecten gatunensis* Toula. *Pecten oxygonum optimum* occurs at Gatun, and near Tuxpan, Mexico. *Pecten condylomatus* is reported from near Tampa, Chattahoochee formation, Florida, and Tuxpan, Mexico. *Pecten gatunensis* is also found at Gatun and Tuxpan. The type specimen of *Turritella tristis* came from Costa Rica. *Turritella tristis* Brown & Pilsbry and several other forms not specifically but generically determined which are characteristic genera of the Bowden stage were also recognized. *Ræta gibbosa* Gabb was described from the Tertiary of Peru and it also occurs in strata equivalent to the Bowden in United States of Colombia. All of these localities are Bowden equivalents or associates as judged by their associated faunas.

The evidence concerning the lower Oligocene or Vicksburg stage is quite deficient and it is impossible to determine any connections at this time.

Beds of Eocene age containing several species common to the Tejon of California occur along the Mexican Gulf border. White limestones in the Isthmus of Tehuantepec may be of Eocene age. The faunal relationships between the Mexican coastal plain and the Tejon of California indicate that there were straits which were probably situated in the Isthmus of Tehuantepec during upper Eocene time. The lack of close faunal relationships during the Martinez-Eocene stage with those of the Midway indicates the opposite conclusion. According to Stanton¹⁴ the Pacific and Texan Cretaceous have no species in common. Although Stanton recognizes the presence of an upper Cretaceous series containing a Pacific fauna resting upon a lower Cretaceous, Comanchian stage at Catorce, he

¹⁴ Stanton, T. W., Jour. Geol., vol. 3, 861, 1895.

states that in no place in the entire region has a commingling of upper Cretaceous faunas of these two provinces been found.

According to Hill,¹⁵ during Cretaceous time the major islands of the Antilles were started on the crests of oceanic volcanoes. These land masses thus built up were submerged in part and the sediments deposited from their erosion contain a fauna of upper Cretaceous age. At the end of Cretaceous time these strata were folded along northwest-southeast axes. In late Eocene and early Oligocene time a profound regional subsidence occurred during which all but the highest tips of the Antilles were covered by the waters of the Caribbean. This subsidence was followed by an uplift in Oligocene time, during which great orogenic movements along east-west axes took place. This was the stage, if at all, of an Antillean continent. Possibly many of the larger islands were connected at this time, and the southern portion of Florida may have been linked with this large Antillean island. This event was succeeded by another great submergence and portions of Mexico and Central America as well as the major portions of the Antilles were largely covered with oceanic waters, the Bowden stage.

According to the work of Scott¹⁶ and Matthew¹⁷ in the study of recent and fossil mammals, any connection of the mainland with the Antilles is very improbable. The species of small sloth found in the Pleistocene beds of Cuba sprang from a single form which evidently reached this locality via one of the raft routes. It appears quite probable that other mammals in Cuba and other islands migrated in this way.

Scott shows that during Miocene time the mammalian faunas of North and South America were entirely distinct. These facts indicate that a period of widespread submergence occurred during the Miocene and the beds bearing the Bowden fauna may well represent this era of subsidence.

Dall¹⁸ has compared the Bowden fauna to that of Bordeaux and the Aquitanian. Guppy¹⁹ has also compared the fauna to the Dax Miocene and the Bordeaux. The age of the Aquitanian has not yet been definitely settled. De Lapparent²⁰

¹⁵ Hill, R. T., *Bull. Mus. Comp. Zool.*, vol. 34, 223, 1899.

¹⁶ Scott, W. S., *History of Land Mammals of the Western Hemisphere*, 1913.

¹⁷ Matthew, W. D., *Climate and Evolution*, *Annal. N. Y. Acad. Sci.*, p. 204, 1915.

¹⁸ Dall, W. H., *Proc. U. S. Nat. Mus.*, vol. 19, 1897.

¹⁹ Guppy, R. J. L., *Geol. Mag.*, Sept., 1874.

²⁰ De Lapparent, *Text Book of Geology*, 1912.

places it as lower Miocene and the Stampian and Tongrian in the Oligocene. Most of the faunal comparisons made by Guppy indicate the same stage, but the Antillean fauna may have developed from an earlier cosmopolitan fauna of upper Eocene age, or we may be dealing with a case of parallel evolution. Most of the forms identified in the Antillean—the corals for example,—by early investigators have been rejected by the investigators of today. Thus Vaughan²¹ rejects all Duncan's²² European species as occurring in the Antilles. It seems to the writer that an Atlantis is quite unnecessary to account for the faunal relationship between the West Indies and the Miocene of Europe. According to Hill, *Orbitoides mantelli*, a characteristic Oligocene form does not occur in the Bowden beds. Thus, the best evidence for Oligocene age has disappeared.

Hill states the date of this fauna as follows: "In my opinion it was during late Miocene and Pliocene time beginning with the Bowden epoch of the Jamaican sequence. Dr. Dall holds that the age of the Bowden beds is late Oligocene. It is my opinion that the stratigraphic relations of these beds in Jamaica indicate a later age. Deferring to Dall's opinion, I have tentatively accepted his conclusions, however, until more field work can be done." Thus diastrophism indicates a Miocene age for Bowden fauna as shown above.

The lack of relationship between Miocene Mammalian faunas of North and South America indicates a widespread submergence at this time.

The Oligocene of the Pacific states contains no forms common to the Bowden fauna. One form, a shark tooth, *Hemipristis serra* Agassiz occurs in the Temblor formation (middle Miocene) near Bakersfield, in a Tertiary formation at Tuxpan, Mexico, an equivalent of the Bowden horizon and in the Maryland Miocene. This shark tooth represents a species much more specialized than usual. One or two other forms from Bakersfield, California, are very close, if not identical to species in the Bowden fauna. As the Tertiary of Lower California is explored, an intergradational fauna should be sought which

²¹ Vaughan, T. W., Some Cretaceous and Eocene Corals from Jamaica, in Hill: Geol. of Jamaica, Bull. Mus. Comp. Zool., vol. 34, 227, 1899.

²² Duncan, P. M., Quart. Jour. Geol. Soc. London, vol. 21, 1-15, 1865.

might show the relations between the Magdalena Bay fauna and that of the California Miocene.

All investigators have recognized a number of living species in this fauna, Gabb 30 to 40 per cent, Moore 8 to 9 per cent, Guppy 20 per cent, Brown and Pilsbry about 5 per cent. These percentages are all greater than is exhibited in the Oligocene of the Pacific Coast and the faunal relations to recent fauna corresponds to our California Miocene. The correct value may be about 5 to 10 per cent. From all evidence available a Miocene age for the Bowden beds appears to be correct.

With wide openings between the Pacific and Atlantic in the Central American region, the trade winds of Miocene time probably drove the waters of the Atlantic through these passages and no Gulf Stream existed. On this account, sharply defined climatic zones were present on both coasts of United States and the faunas of the tropics were sharply separated from those of the temperate regions. This oceanic current condition accounts quite satisfactorily for the scantiness of species common to the California middle Miocene and the Magdalena Bay fauna on the west coast.

In summary: The Panama Portal was closed during Cretaceous time and this gateway was not opened until upper Eocene time. During a period of widespread uplift—Oligocene time—the Antilles were probably connected with southern Florida and possible Central America. Following this emergent stage, a wide submergence occurred during Miocene time, marked by the Bowden horizon. At this period North and South America were disconnected and wide straits in Central America were formed. Since the Miocene, the Panama portal has remained closed until Colonel Goethals and his men trenched the narrow barrier by the Panama Canal.